# ~~CLAIMS~~

1. ~~A system for realizing at least one channel of optical filtering, the system comprising:~~

   a. ~~at least one Fourier transform plane;~~

   b. ~~at least one positive-definite optical transfer function element~~

   ~~wherein optical filtering effects of non-positive-definite optical transfer functions are realized through use of at least one positive-definite optical transfer function element outside the Fourier transform plane.~~

2. ~~The system of claim 1 where only positive-definite optical filtering elements are used to realize non-positive-definite optical transfer functions.~~

3. ~~The system of claim 1 where at least one of the position and amplitude distribution of a positive-definite optical filtering element is determined through use of fractional Fourier transform methods.~~

4. ~~The system of claim 1 where at least one of position and amplitude distribution of a positive-definite optical filtering element is determined through use of Hermite function expansions.~~

5. ~~The system of claim 4 where approximations are used to determine at least one of position or amplitude distribution of at least one optical filtering element.~~

6. ~~The system of claim 1 where at least one programmable light modulator is used as an optical filtering element.~~

7. ~~The system of claim 6 where at least one programmable light modulator is controlled by optical control signals.~~

8. ~~The system of claim 1 where the system is used to optically perform general computing functions.~~

9. ~~The system of claim 8 where general computing functions involve complex-valued arithmetic.~~

10. ~~The system of claim 1 where the optical system includes at least one of a lens, graded-index optical medium, or graded-index optical environment.~~

11. ~~The system of claim 1 where the resulting optical processing system is realized with integrated optics.~~

12. ~~The system of claim 11 where the resulting integrated optics based optical processing system is realized monolithically.~~

13. ~~The system of claim 11 where the resulting monolithic integrated optics based optical processing system is fabricated by at least one of photolithography or beam-controlled fabrication methods.~~

14. ~~A method for realizing at least one channel of optical filtering, the method comprising:~~

    a. ~~receiving image and/or video data from at least one of a recorded or real-time image source;~~

    b. ~~the existence of at least one Fourier transform plane;~~

c. ~~determining at least one parameter relating to at least one fractional Fourier transform operation; and~~

d. ~~determining at least one parameter relating to at least one of position and amplitude distribution of at least one positive-definite optical transfer function element~~

~~wherein optical filtering effects of non-positive-definite optical transfer functions are realized through use of at least one positive-definite optical transfer function element outside the Fourier transform plane.~~

15. ~~The method of claim 14 where only positive-definite optical filtering elements are used to realize non-positive-definite optical transfer functions.~~

16. ~~The method of claim 14 where at least one of position and amplitude distribution of a positive-definite optical filtering element is determined through use of fractional Fourier transform methods.~~

17. ~~The method of claim 14 where at least one of the position and amplitude distribution of a positive-definite optical filtering element is determined through use of Hermite function expansions.~~

18. ~~The method of claim 27 where approximations are used to determine the position or amplitude distribution of at least one optical filtering element.~~

19. ~~The method of claim 14 where at least one programmable light modulator is used as an optical filtering element.~~

20. ~~The method of claim 19 where at least one programmable light modulator is controlled by optical control signals.~~

21. ~~The method of claim 14 where the method is used to optically perform general computing functions.~~

22. ~~The method of claim 21 where general computing functions involve complex-valued arithmetic.~~

23. ~~The method of claim 14 where the optical system includes at least one of a lens, graded-index optical medium, or graded-index optical environment.~~

24. ~~The method of claim 14 where the resulting optical processing method is realized with integrated optics.~~

25. ~~The method of claim 24 where the resulting integrated optics based optical processing system is realized monolithically.~~

26. ~~The method of claim 24 where the resulting monolithic integrated optics based optical processing system is fabricated by at least one of photolithography or beam-controlled fabrication methods.~~

27. ~~A system for adjusting optical phase shift of an optical transfer function, the system comprising:~~

    a. ~~a controllable optical phase shift transfer function element with index of refraction of the element is changed in response to a control signal.~~

28. ~~The controllable optical phase shift transfer function element of claim 27 employed in a two-dimensional array for processing two-dimensional optical signals.~~

29. ~~A method for adjusting optical phase shift of an optical transfer function, the method comprising:~~

    a. ~~a controllable optical phase shift transfer function element with index of refraction of the element is changed in response to a control signal.~~

30. ~~The method of claim 29 employed in a two-dimensional array for processing two-dimensional optical signals.~~

31. ~~A system for adjusting optical phase shift of an optical transfer function, the system comprising:~~

    a. ~~a controllable optical phase shift transfer function element with effective transmission distance of light transmitted through the element changeable in response to a control signal.~~

32. ~~The controllable optical phase shift transfer function element of claim 31 employed in a two-dimensional array for processing two-dimensional optical signals.~~

33. ~~A method for adjusting optical phase shift of an optical transfer function, the method comprising:~~

    a. ~~a controllable optical phase shift transfer function element with effective transmission distance of light transmitted through the element changeable in response to a control signal.~~

34. ~~The method of claim 33 employed in a two-dimensional array for processing two-dimensional optical signals.~~

35. ~~A system for synthesizing optical Fractional Fourier transform operations on an optical signal, the system comprising:~~

    a. ~~at least one controllable optical phase shift transfer function element.~~

36. ~~The system of claim 35 where at least two controllable optical phase shift transfer function elements are stacked together.~~

37. ~~The system of claim 35 where the at least one controllable optical phase shift transfer function element is used to synthesize the effect of at least one of varying the focal length and varying the separation distance of a lens or system of lenses.~~

38. ~~The system of claim 35 used to realize at least one of a lens focus effect and/or lens zoom effect controllable by control signals.~~

39. ~~The system of claim 35 where the system is used to optically perform general computing functions.~~

40. ~~The system of claim 39 where the computing functions involve complex-valued arithmetic.~~

41. ~~A method for synthesizing optical Fractional Fourier transform operations on an optical signal, the method comprising:~~

    a. ~~at least one controllable optical phase shift transfer function element.~~

42. ~~The method of claim 41 where at least two controllable optical phase shift transfer function elements are stacked together.~~

43. ~~The method of claim 41 where the at least one controllable optical phase shift transfer function element is used to synthesize the effect of at least one of varying~~

~~the focal length of a lens and varying the separation distance of a lens or system of lenses.~~

44. ~~The method of claim 41 used to realize at least one of a lens focus effect and/or lens zoom effect controllable by control signals.~~

45. ~~The method of claim 41 used to optically perform general computing functions.~~

46. ~~The method of claim 55 where the computing functions involve complex-valued arithmetic.~~

47. ~~A system for realizing at least one channel of optical filtering, the system comprising:~~

    a. ~~at least one non-quadratic graded-index material; and~~

    b. ~~one controllable optical filtering element.~~

48. ~~A system for realizing at least one channel of optical filtering, the system comprising:~~

    a. ~~at least one non-quadratic graded-index material; and~~

    b. ~~one controllable optical filtering element.~~

## ~~ABSTRACT~~

[0020] ~~The Fourier transforming properties of simple lenses and related optical elements is well known and heavily used in a branch of engineering known as "Fourier Optics." Classical Fourier Optics allows for relatively easy, inexpensive, flexible signal processing of images by using lenses or other means to take two-dimensional Fourier transforms of an optical wavefront and using a translucent plate or similar means in this location to introduce an optical transfer function operation on the optical wavefront. The image processing possibilities have historically been limited to transfer functions that mathematically are "positive-definite," i.e. those which affect only amplitude and do not introduce varying phase relationships. The method of this invention uses Fractional Fourier transform properties of lenses or other elements or optical environments to introduce one or more positive-definite optical transfer functions at various locations outside the Fourier plane so as to realize or closely approximate arbitrary non-positive-definite transfer functions. Designs can be straightforwardly obtained by methods of approximation. The invention provides for the application of these methods to create single and multiple channel controllable optical processors which may be used for image or other types of computation, including computation with complex-valued arithmetic, visual color, and wide-spectrum optical signals. The methods can be extended for other arrangements, such as phase-shifting filter elements and non-quadratic graded-index materials (which do not~~

~~naturally invoke the Fractional Fourier transform operation). Applications of the invention include integrated optics, optical computing systems, particle beam systems, radiation accelerators, astronomical observation methods, and controllable lens systems.~~